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Impact of the Built Environment and Bicycling Psychological Factors on the Acceptable Bicycling Distance of Rural Residents

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Abstract: The ability to understand bicycling behavior in China's rural areas is critical in constructing an improved, sustainable, countryside amid the rapid urbanization in the country. This study analyzes the influence of individual bicycling psychology, objective, and perceived built environment on the acceptable bicycling distance of rural residents. This research is conducted by controlling for the socio-demographic characteristics of the residents on the bases of a face-to-face questionnaire survey and an on-site measurement. Exploratory factor analysis shows three attitudinal common factors on bicycling infrastructure, namely, bicycling ancillary facilities, bicycle lane conditions, and safety, and two bicycling motivation factors, namely, convenience and other motivations. Multiple linear regression was estimated and results of the models were consistent. Individual bicycling psychology and built environment factors significantly influence the acceptable bicycling distance of rural residents. The socio-demographic variables insignificantly influence the acceptable bicycling distance, which is inconsistent with the existing literature. The research results provide a broad empirical base for the complex relationships among individual bicycling psychological factors, objective and perceived built environment, and bicycling behavior. This study presents the first research on bicycling in Chinese rural areas and provides guidance for the development of effective countermeasures in constructing ecovillages.

Keywords: rural built environment; bicycling distance; bicycling psychological factors; bicycling behavior; multiple linear regression model

1. Introduction

Cities worldwide promote the use of bicycles for transportation to achieve physical and mental health, zero emission, and space saving [1]. Bicycling is a healthy mode of transportation that promotes physical activity, the health benefits of which have been widely recognized [2,3]. Extensive evidence suggests that physical activity reduces the risk of cardiovascular diseases, diabetes, and colon, breast, and endometrial cancer [4,5]. Bicycling can also enhance aerobic lung function and has been proven to be able to facilitate the achievement of the recommended lung function levels [6–8]. Furthermore, regular bicycling can improve the personal health of residents by reducing their sedentary lifestyle [9,10]. Bicycle riding is likewise considered environmentally sustainable compared with motor vehicle travel because of low-energy consumption and zero emission of pollutants [11]. Therefore, the use of bicycles can reduce air and noise pollution [12]. This implication is crucial for the future transition to a sustainable city. Evidently, promoting active transportation through bicycling and walking is recognized as being among the effective methods to build an environment-friendly and healthy city [13,14]. In the past two decades, cities and metropolitan areas in the US have used a significant proportion of their federal funds to improve their respective bicycling systems [15]. Moreover, bicycles offer a variety of commuting benefits, including economy, reliability, and speed, thereby making bicycles a suitable vehicle for travel in many cities and suburbs [16,17]. However, empirical evidence remains limited despite the expanding interest in linking the built environment of transportation and health sciences with bicycling [18–20].

Bicycling is a sustainable transportation mode that promotes physical and mental health. However, rapid rural urbanization in China has resulted in the annual decline in the number of bicycles per 100 rural households in the country, whereas the number of cars has been increasing during the same period (see Figure 1) [21]. Rural China remains in the process of continuous construction, which potentially leads to minimal use of bicycles. Hence, the demand of rural residents for bicycling facilities should be explored and psychological factors, such as attitude, preference, motivation, and purpose of bicycling, should be studied. These factors are conducive to ecological rural planning and can effectively encourage rural residents to have low-carbon and healthy travel. The current study attempts to fill in this gap in the literature, explore the impact of the rural built environment and the psychological determinants of rural residents on the acceptable bicycling distance, and provide scientific theoretical guidance to further plan and develop ecovillages.

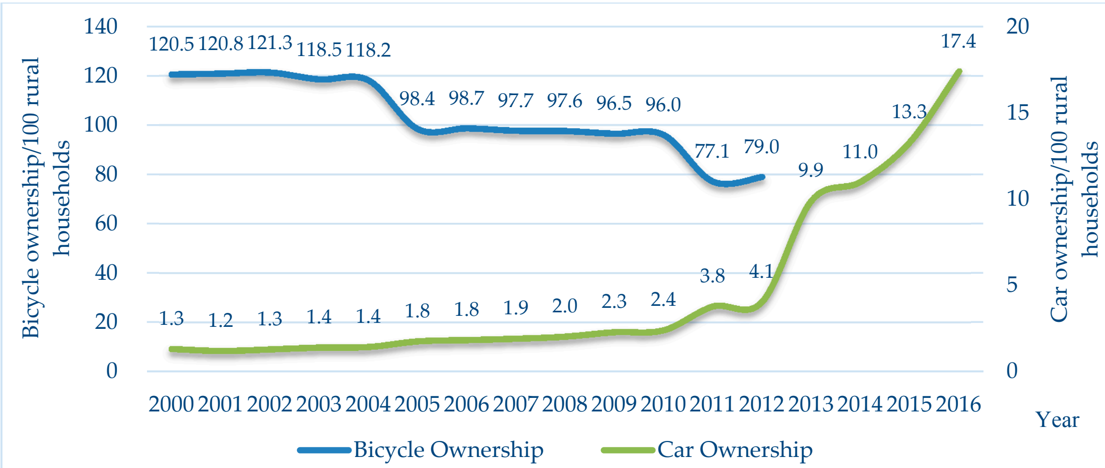

Figure 1. Household car and bicycle ownerships in rural China. Note: The data of bicycle ownership is from the Statistical Yearbook of China, but since the statistical yearbook of 2013, bicycle ownership has not been counted. Therefore, the bicycle ownership plot stops after the year 2012.

The remainder of this paper is organized as follows. Section 2 discusses the existing literature on the influencing factors of bicycling behavior. Section 3 presents the materials and method used in the current study. This section also describes the data collection and variable and model specifications. Section 4 discusses the results of the proposed model. Section 5 presents the strengths and limitations of this study. Lastly, Section 6 presents the conclusion and policy implications.

2. Literature Review

Numerous factors affect people's decision to ride a bicycle, including the traffic volume of motor vehicles [8,22,23], safe and reliable bicycling infrastructure [24,25], and socio-demographic characteristics [26,27]. An increasing number of studies have considered the impact of psychological determinants on bicycling [28–30]. Moreover, such natural factors as landscape, weather, and terrain may determine the decision of a person to ride a bicycle [31]. Hence, the built environment, individual bicycling psychology, and socio-demographic characteristics are the three main factors affecting bicycling behavior [32,33].

2.1. Built Environment Factors

Various studies have demonstrated the impact of the built environment attributes on bicycling behavior, including the impact of land use density and diversity, street connectivity, and distance between departure and destination. Intensive residential areas [34] and mixed land use [35] reduce travel distance and increase the proportion of bicycling transportation. By contrast, heavy traffic volume [36] and increase in travel distance [31,36] are negatively correlated with bicycling trips. Bicycle lane density, street connectivity, and infrastructure accessibility are positively correlated with commuter bicycling frequency [2,37]. Bicycle parking and destination facilities, such as shower and changing rooms, are positively correlated with bicycling frequency [38]. The connectivity of transportation network, particularly bicycle road infrastructure, traffic flow and speed, and road surface quality and grade, are correlated with the use of bicycles [33,39]. Research has also shown that cyclists considerably focus on bicycling facilities [36,40]. Dedicated bicycle lanes and destination facilities for bicycling can encourage people to ride bicycles [41]. Recent studies have suggested that, wherever possible, the measurement data for objective and subjective built environments should be included because different correlations exist between the objective and perceived built environment for the same environmental attributes [42–45]. Objective measures are often derived (using geographic information systems) from systematic observations, audits, and calculations based on existing spatial data (e.g., street networks and land use data). By contrast, subjective measures are often derived from self-reported data, thereby reflecting the subjectiveness of the respondents on an environment [46]. Different people may have varying perceptions of the same built environment, thereby prompting them to behave differently [47]. For example, perceived traffic safety is different from the objective measures of traffic safety, although both aspects will affect the decision to bike [48]. The impact of the built environment on bicycling behavior has attracted the attention of many scholars, although the theoretical debate has never stopped. After considering individual bicycling psychology, the influence of the built environment on bicycling behavior will become substantially complicated.

2.2. Psychological Factors of Bicycling

Many people continue to choose not to ride a bicycle, even though the supportive bicycling infrastructure is enhancing the opportunities for and safety of bicycling. Frequently, a good bicycling infrastructure is not necessary. Despite the lack of good bicycling facilities, some people continue to ride bicycles regularly just because they like bicycling [11]. Accordingly, people's preference for bicycling is an important predictor of whether they ride bicycles. Hence, individual bicycling psychological factors are crucial in analyzing bicycling behavior [28–30]. The attitude toward the benefits of bicycling directly affects bicycling behavior. Personal attitudes include the preference for biking activities and perceived physical and mental health benefits of bicycling, which are highly relevant to this activity [32,49]. Hence, liking bicycling is the most important factor in explaining the ownership and regular use of bicycles, given the good bicycling infrastructure [49]. A few studies have shown that liking bicycling is also closely related to bicycling distance and the decision to use bicycles [49,50]. These findings suggest that the role of bicycling psychology can no longer be disregarded. Furthermore, additional empirical research should be conducted to confirm whether our understanding of attitudes is consistent with that in various studies and to formulate effective policies that will encourage residents to ride bicycles. For example, many cities in the Netherlands, Denmark, and Germany plan to stimulate bicycling interest and enthusiasm for people of all age groups [34]. Therefore, individual psychological determinants, such as attitude, perception, and preference of cyclists, are important in explaining bicycling behavior. The majority of the related studies have shown that even after controlling for the statistically significant effects of individual bicycling psychological factors, the impact of the built environment factors remains statistically significant, thereby complicating the influence of the built environment on travel behavior [51–53].

2.3. Socio-Demographic Factors

Socio-demographic characteristics significantly impact the bicycling behavior of residents. Gender and income are the two demographic factors that substantially affect bicycling behavior in the majority of the research conducted. In particular, women are concerned with motor vehicles [26,27]. Among commuter cyclists, women prefer to ride away from motorized lanes [54]. Therefore, improving bicycle lanes, lane forms, and bicycle facilities significantly increases separation from motor vehicles, thereby possibly increasing the bicycling activities of women [55]. Gender also affects the perception of bicycling risk and behavior selection. One study has determined that 65% of male cyclists will continue to opt for riding bicycles even if they perceive the bicycling risks, whereas only 50% of women will continue to ride bicycles under the same bicycling risk perception [56]. Income has a decisive role in the choice of transportation mode. People who do not own a car are likely to walk or bike [57]. Thus, bicycle users constitute the majority of the households with annual income below USD 50,000 [58]. However, voluntary and involuntary bicycling should be distinguished from each other [59]. Many high-income cyclists voluntarily choose bicycling as a form of entertainment, exercise, and other personal purposes. Therefore, the individual psychological determinants of cyclists influence bicycling behavior after controlling for the socio-demographic variables [60].

Recent studies on bicycling behavior have focused on bicycling mode choice, route selection [32,33], and exploration of the factors that affect bicycling frequency [2,12]. However, only a few studies have focused on bicycling distance. Meanwhile, empirical studies have mainly concentrated on cities and disregarded the rural areas, particularly in China. Hence, the findings of this literature review justify the importance of exploring the impact of key factors, such as bicycling psychology, on the acceptable bicycling distance of rural residents in China.

3. Materials and Method

3.1. Model Settings

Exploratory factor analysis (EFA) is first deployed to identify important broad attitude on bicycling condition and bicycling motivation. Two models are adopted in this study to observe the stability of the relationship between the independent and dependent variables. The EFA results will be used in linear regression to explore the influence of bicycling psychological factors and built environment on acceptable bicycling distance of rural residents.

The multiple linear regression model will be used to study the relationship between the dependent variable and at least one independent variable [61]. The general form of the linear regression model can be written as follows:

$$y = x_1\beta_1 + x_2\beta_2 + \cdots + x_n\beta_n + \varepsilon = x_i{}'\beta_i + \varepsilon\ , \tag{1}$$

where, y refers to the vector of the dependent variables, which is the acceptable bicycling distance that the respondents filled in, thereby making y a continuous variable, x_i refers to the vector of the independent variables and mainly refers to the psychological factors and built environment, and ε is the vector of the errors in the equation.

3.2. Data Collection and Descriptive Analysis

The sample villages were selected from the rural Sichuan Province for its immense economic output and rapid urbanization. The economic aggregate of the Sichuan Province ranks second in Central and Western China and first in Western China with a per capita GDP (Gross Domestic Product) of 44,651 Yuan. At the end of 2018, the number of permanent residents in the Sichuan Province was 83.41 million and the registered population was 91.218 million. The urbanization rates involving the permanent residents and registered population were 52.29% and 35.87%, respectively. Accordingly, considerable changes in rural household vehicle ownership have occurred because of rapid urbanization. For example, the car ownership rates of rural households were 12.5% and 1.0% by the end of 2016 and 2000, respectively. However, the bicycle ownership rate declined rapidly (National Bureau of Statistics of the People's Republic of China) [21] (Figure 2). Travel behavior would change owing to substantial changes in rural household vehicle ownership. Therefore, an empirical study should be conducted in rural Sichuan for rural revitalization and new rural construction.

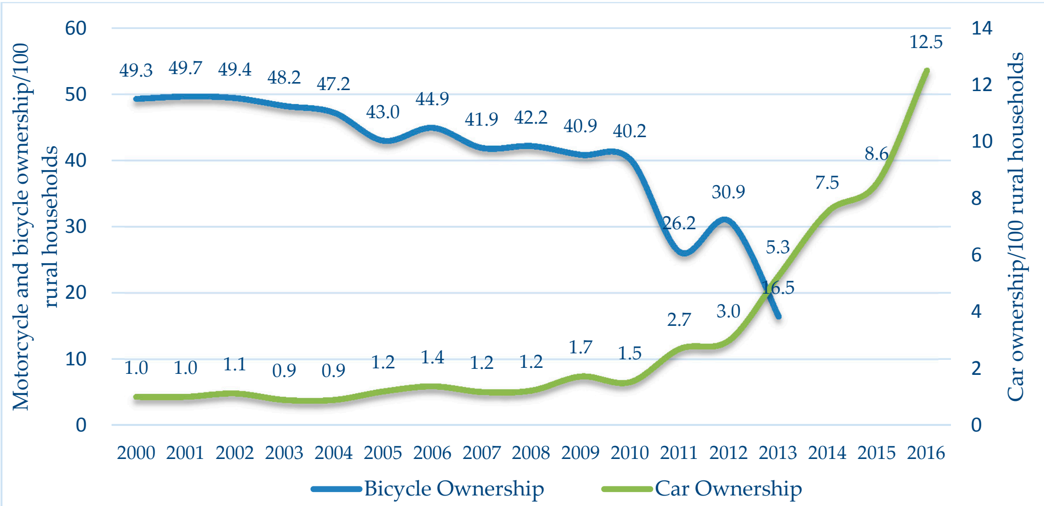

Figure 2. Household car and bicycle ownerships in rural Sichuan. Note: The data of bicycle ownership is from the Statistical Yearbook of China, but since the statistical yearbook of 2014, bicycle ownership has not been counted. Therefore, the bicycle ownership plot stops after the year 2013.

This study selected seven villages: three new concentrated villages and four traditional scattered villages. Additional details of the sample and data collection for this study are included in the current authors' previous research [62,63]. Eventually, we prepared 374 valid rural household questionnaires for this study. Table 1 shows the socio-demographic attributes of the rural respondents. Figure 3 presents the map of the study area's location and sample village location.

Table 1. Socio-demographic attributes of the rural respondents.

Variable	Level	Number of Sample	Percent (%)
Male	0 for female	226	60.43
	1 for male	148	39.57
Age	1 represent age 16–25	47	12.57
	2 represent age 25–40	65	17.38
	3 represent age 41–50	112	29.95
	4 represent age 51–60	80	21.39
	4 represent age 61–70	70	18.72
Income	1 represents 0	116	31.02
	2 represents 0–5 thousand yuan	38	10.16
	3 represents 5–10 thousand yuan	80	21.39
	4 represents 10–20 thousand yuan	60	16.04
	5 represents 20–40 thousand yuan	59	15.78
	6 represents >40 thousand yuan	21	5.61
Acceptable bicycling distance (KM)	(0, 1)	65	17.38
	(1, 2)	108	28.88
	(2, 3)	88	23.53
	(3, 4)	44	11.76
	(4, 5)	56	14.97
	(5, 8)	13	3.48

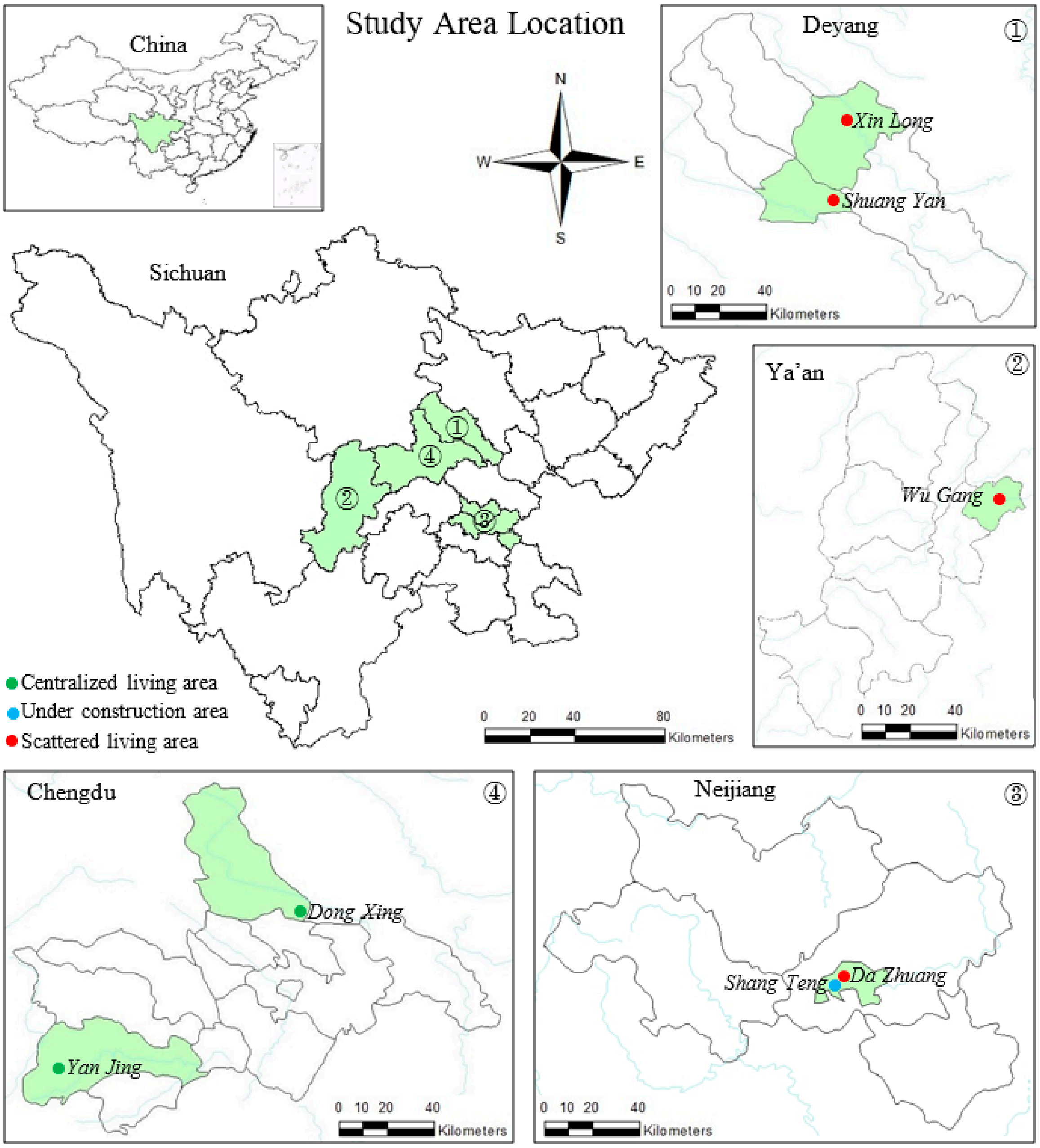

Figure 3. Map of the study area's location and the sample village location. Note: The map is from the National Bureau of Surveying, Mapping, and Geographic Information.

Apart from conducting a household survey, we also measured the actual built environment basic data on-site, further details of which are included in the current authors' previous research [62,63]. Table 2 shows the basic data of the actual built environment that were measured on-site.

Table 2. Basic data of the actual built environment.

Name of Villages	Valid Sample Number	Distance to Nearest Hospital (KM)	Distance to Nearest Market (KM)	Distance to Nearest School (KM)	Distance to Nearest Public Transportation Station (KM)
Dazhuang	57	0.05	3.00	0.50	2.50
Wugang	56	0.20	3.50	2.50	0.2
Shuangyan	53	0.60	1.60	1.60	0.50
Xinlong	61	4.90	0.80	3.00	1.20
Doxing	58	0.00	0.00	2.10	3.90
Shangteng	49	1.60	1.50	1.50	0.69
Yanjing	40	1.70	1.50	0.50	0.50

3.3. *Variable Settings*

3.3.1. Socio-Demographic Variables

The literature review shows that socio-demographic factors significantly influence travel behavior, such as acceptable bicycling distance. Accordingly, this study selects basic such socio-demographic information as (1) gender, (2) age, and (3) income.

3.3.2. Psychological Variables of Bicycling

Four types of psychological variables of bicycling were mainly considered to explore the effects of the psychological factors of bicycling on the acceptable bicycling distance for individuals [12,49,50].

(1) Attitude on bicycling infrastructures. The respondents were asked to evaluate 13 statements using a 5-point Likert scale that ranges from 1 (i.e., strongly negative to ride bicycles) to 5 (i.e., strongly positive to ride bicycles) for the following question: Are you willing to ride bicycles when the following conditions are satisfied?

(2) Bicycling motivation. The respondents were asked to evaluate eight statements using a 5-point Likert scale that ranges from 1 (i.e., strongly disagree) to 5 (i.e., strongly agree) for bicycling motivation.

EFA was performed using SPSS 23.0 to identify the latent structures underlying the aforementioned attitude and motivation response. Three common factors of attitude on bicycling infrastructure conditions and two common factors of bicycling motivation were eventually obtained. The common factors will enter the multivariate models.

(3) Bicycling purpose. The respondents were asked to select their bicycling purpose if they want to ride bicycles from the given seven options. The seven bicycling purposes were transferred to seven binary variables (1 = yes, 0 = no).

(4) Riding preference. To accurately collect riding preference data, the respondents were asked to rank car, public transportation, motorcycle, bicycle, and electric bicycle on the basis of their preferences. The scale ranges from 5 (i.e., most favorite travel mode) to 1 (i.e., least favorite travel mode). Lastly, bicycle, motorcycle, and electric bicycle were selected as the riding preference variables using the given numbers (1–5).

3.3.3. Built Environment Variables

This study focuses on the objective and perceived built environment information on the bases of the on-site measurement of the built environment and perceived data of the respondents. Moreover, this research mainly considers four destinations to explore the connection between the objective and perceived built environment. All destinations are in the most acceptable bicycling distance scope (i.e., 5 km) (see Figure 4). First, objective built environment indicators were measured on-site using the Baidu navigation app (see Table 3). Second, the respondents were asked to assess the four statements using a 5-point Likert scale that ranges from 1 (strongly disagree) to 5 (strongly agree) to measure the perceived built environment indicators (see Table 3).

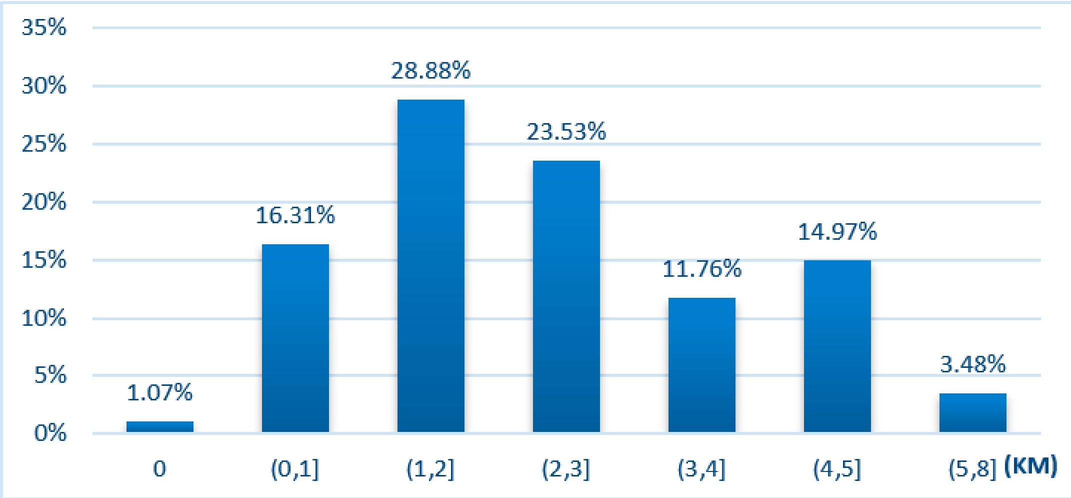

Figure 4. Acceptable bicycling distances of the rural residents of Sichuan.

Table 3. Objective and perceived built environment variables.

	Objective Built Environment Indicators	Perceived Built Environment Indicators
1	Distance to nearest hospital from village center. (O_H)	It is very convenient to hospital. (P_H)
2	Distance to nearest market from village center. (O_M)	It is very convenient to market. (P_M)
3	Distance to nearest school from village center. (O_S)	It is very convenient to school. (P_S)
4	Distance to nearest public transportation station from village center. (O_P)	It is very convenient to public transportation station. (P_P)

3.3.4. Dependent Variable

The acceptable bicycling distance of rural residents is the dependent variable in this study. The respondents were asked to indicate the bicycling distance that is acceptable to them. The preliminary statistical analysis indicated that the maximum, minimum, and average acceptable bicycling distances are 8, 0, and 2.873 km, respectively (see Table 3). The dependent variable was dealt with in two ways to accurately analyze the influence of the independent variables on the dependent variable. First, the acceptable bicycling distance data filled out by the respondents is retained because it is a continuous variable. In particular, the data were entered into the multiple linear regression model as a continuous dependent variable. Second, an ordered variable was processed using serial numbers to indicate the acceptable bicycling distance of the respondents. The data processing was as follows: 0 represents 0 km, 1 represents an acceptable bicycling distance of over 0 km and below or equal to 1 km, 2 represents the distance above 1 km and below or equal to 2 km, 3 represents the distance above 2 km and below or equal to 3 km, and so on. Lastly, 6 represents distance above 5 km and below or equal to 8 km. Figure 4 shows the frequency statistics of the ordered variable. The most number of people who can accept a bicycling distance above 1 km and below 2 km reached 28.88%, followed by over 2 km and below or equal to 3 km. Over 50% of the respondents believe that bicycling distance above 1 km and below or equal to 3 km is acceptable. Table 4 shows all the variables. The variance inflation factor (VIF) test indicates that this study has no multicollinearity problem.

Table 4. Descriptive statistical summary of the variables used in this study.

Variables	Mean	S.D	Minimum	Maximum	Type	VIF
Dependent Variables						
Acceptable Bicycling Distance (km)	2.874	1.433	0.000	6.000	Ordinal (0, 1, 2, 3, 4, 5, 6)	–
Acceptable Bicycling Distance of the Original Data (km)	2.873	1.542	0.000	8.000	Continuous	–
Independent Variables						
Male	0.396	0.489	0.000	1.000	Binary: 0-female/1-male	1.257
Age	3.163	1.270	1.000	5.000	Nominal (5 levels)	1.273
Income	1.407	1.730	0.000	15.000	Continuous	1.374
Cycling ancillary facilities	0.000	0.999	(4.018)	4.177	Common factor	1.193
Bicycle lane conditions	0.000	0.999	(2.752)	3.383	Common factor	1.172
Safety	0.000	0.999	(3.554)	3.885	Common factor	1.200
Other motivations	0.000	0.999	(2.922)	2.233	Common factor	1.405
Convenient	0.000	0.999	(3.058)	2.104	Common factor	1.216
Physical activity	0.489	0.500	0.000	1.000	Binary: 0-no/1-yes	1.390
Go to work/school	0.160	0.367	0.000	1.000	Binary: 0-no/1-yes	1.155
Bike with children	0.147	0.354	0.000	1.000	Binary: 0-no/1-yes	1.209
Go shopping	0.340	0.474	0.000	1.000	Binary: 0-no/1-yes	1.537
Visit friends	0.267	0.443	0.000	1.000	Binary: 0-no/1-yes	1.308
To entertainment	0.112	0.316	0.000	1.000	Binary: 0-no/1-yes	1.174
Others	0.134	0.340	0.000	1.000	Binary: 0-no/1-yes	1.168
Liking riding motorcycles	2.631	1.258	1.000	5.000	Ordinal	1.441
Liking riding electric bicycles	3.393	1.123	1.000	5.000	Ordinal	1.164
Liking bicycling	2.693	1.350	1.000	5.000	Ordinal	1.395
O_P (see Table 3)	1.426	1.282	0.200	3.900	Continuous	2.445
O_M (see Table 3)	1.695	1.155	0.000	3.500	Continuous	2.967
O_S (see Table 3)	1.742	0.880	0.500	3.000	Continuous	1.688
O_H (see Table 3)	1.313	1.702	0.000	4.900	Continuous	2.706
P_S (see Table 3)	3.439	0.971	1.000	5.000	Ordinal	2.906
P_M (see Table 3)	3.508	0.939	1.000	5.000	Ordinal	3.810
P_P (see Table 3)	3.179	1.118	1.000	5.000	Ordinal	2.204
P_H (see Table 3)	3.634	0.839	1.000	5.000	Ordinal	1.498

4. Results and Discussion

This section presents the results of the analysis. First, we present the descriptive statistics for bicycling psychology, including the stated bicycling purpose, motivation, attitudes on bicycling infrastructure conditions, preferences for bicycling, riding motorcycles, and riding electric bicycles. Thereafter, the current section provides the EFA results of the latent attitude and motivation and the multiple linear regression of the acceptable bicycling distance.

4.1. Attitude on Bicycling Infrastructure Conditions of the Rural Residents of Sichuan

Figure 5 shows the results of the questionnaire survey on attitude. Over half of the respondents believe that every bicycle infrastructure condition (except shower facilities at the destination) encourages them to ride a bicycle. Over 70% of the respondents agree that these bicycling infrastructures, such as good-quality route surface, bicycle lanes separated from motor vehicle lanes, safety of bicycle lanes, and sufficiently wide bicycle path, encourage them to ride bicycles. Therefore, the good conditions of bicycle lanes have the most evident positive impact on bicycling for the current rural residents of Sichuan, followed by other ancillary facilities, such as bicycle parking, traffic lights, shade, and shower facilities. These statistical results are consistent with the actual situation in Sichuan without efficient specialized bicycle infrastructure.

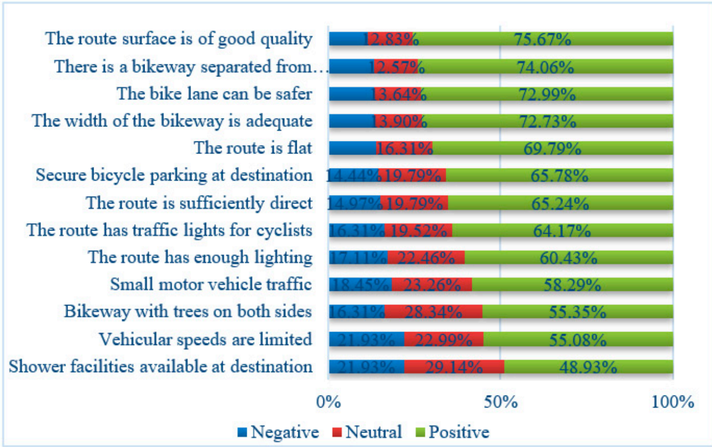

Figure 5. Attitude on bicycling infrastructure conditions for rural residents.

4.2. Bicycling Motivation of the Rural Residents of Sichuan

Figure 6 shows the preliminary statistics. A total of 83.42% of the respondents believe that bicycling is beneficial for physical and mental health, although an only few of them selected physical activity as their bicycling purpose. Over 75% of the respondents believe that bicycling is beneficial to the environment, bicycle parking, and money saving. Over 60% of the respondents believe that bicycling can ease traffic congestion and is also interesting. A total of 34.22% of the respondents disagree with the idea that "bicycling is fast," 34.22% of them agree with such statement. The respondents believe that bicycling does not have a fast advantage in speed compared with other bicycling motivations [12].

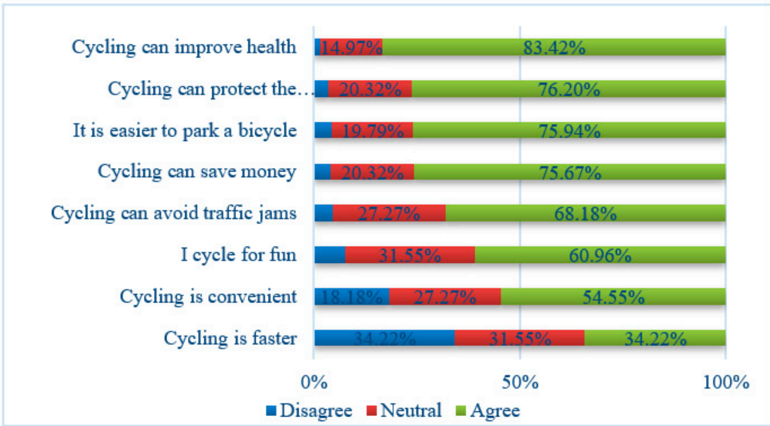

Figure 6. Bicycling motivations of the rural residents of Sichuan.

4.3. Bicycling Purpose of the Rural Residents of Sichuan

Figure 7 shows the distribution of the bicycling purpose of the rural residents based on the preliminary statistics. A total of 46.26%, 33.96%, and 27.27% of the respondents selected going shopping, visiting friends, and going to work and school, respectively. Only 10.70% and 13.64% of the respondents selected physical activity and recreation options respectively, as bicycling purposes. These two options have the lowest selection rates. This finding is inconsistent with that of Fu and Farber [12], who conducted an investigation in Salt Lake City and found that bicycling is mainly a physical and recreational means of traveling for residents of this city. This finding shows a certain gap in the living conditions of residents between China and developed Western countries between urban and rural areas in China. These developments are consistent with the current situation in rural China.

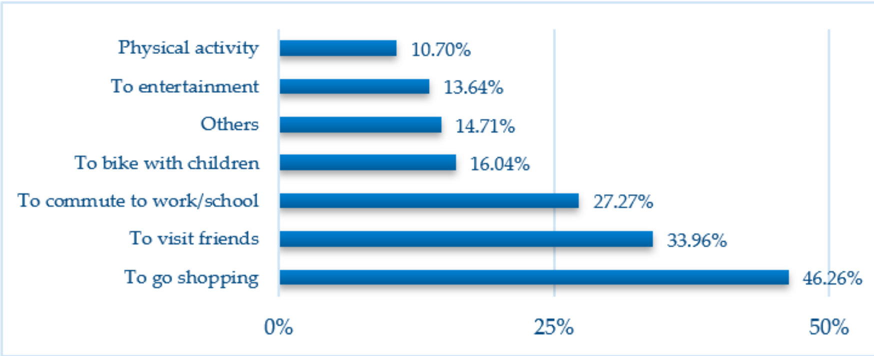

Figure 7. Bicycling purposes of the rural residents of Sichuan.

4.4. Preferences for Riding Bicycles, Motorcycles, and Electric Bicycles

Figure 8 shows the statistical results of the respondents' travel model preference. Their preference for public transportation and private cars is relatively more dispersed compared with their riding preferences. A total of 27.27% of the respondents expressed that they prefer bicycling, whereas 48.93% do not like bicycling. However, preference for electric bicycles is evidently higher than that of bicycles. A total of 46.79% of the respondents said that they prefer electric bicycles, whereas only 22.46% did not prefer this mode of transportation. The respondents' preference for motorcycles is more consistent than that for bicycles. This study mainly considers the influence of the riding preferences of rural residents on the acceptable riding distance. Therefore, the current research eventually chooses the preference data of bicycles, motorcycles, and electric bicycles to enter the multivariate models.

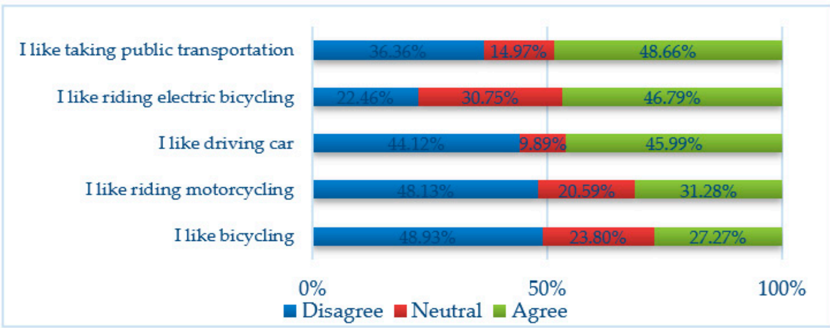

Figure 8. Travel mode preferences of the rural residents of Sichuan.

4.5. Analysis of the Exploratory Factor Analysis (EFA) Results

The Kaiser–Meyer–Olkin (KMO) and Bartlett's tests were used to investigate the factorability of individual attitudes to bicycling infrastructure conditions and bicycling motivation variables. The values for the KMO and Bartlett's tests were 0.956 and 0.809 respectively, thereby indicating that the data are suitable for EFA. Tables 5 and 6 list the items.

EFA identifies three common factors for the attitude to bicycling conditions. The identified factors explain 79.196% of the variance, while the number of factors is reduced from 13 to 3. EFA also identifies two bicycling motivation factors, which explain 59.445% of the variance, while the number of factors is reduced from 8 to 2. Therefore, the EFA results indicate that the number of variables reduced is considerably less than the information loss. Accordingly, the common factors of "bicycling condition attitude" and "bicycling motivation" can be interpreted and represented. Thereafter, the extracted components can be used in the linear regression and can effectively represent the bicycling condition attitude and bicycling motivation of the respondents.

Table 5. Exploratory factor analysis (EFA) results of attitude on bicycling condition.

The Items of Attitude on Bicycling Condition	Component		
	Cycling Ancillary Facilities	**Bicycle Lane Conditions**	**Safety**
The route has traffic lights for cyclists	0.793		
Shower facilities available at destination	0.704		
Vehicular speeds are limited	0.633		0.625
The bike lane can be safer	0.632	0.591	
The route has enough lighting	0.630		
The route is flat	0.608	0.600	
Bikeway with trees on both sides	0.592	0.556	
The width of the bikeway is adequate		0.828	
The route surface is of good quality		0.790	
The route is sufficiently direct		0.780	
Small motor vehicle traffic			0.766
Secure bicycle parking at destination	0.582		0.623
There is a bikeway separated from traffic			0.618
% of Variance	30.125%	29.686%	19.385%
Cumulative	30.125%	59.811%	79.196%
Eigenvalues	3.916	3.859	2.520

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Table 6. EFA result of bicycling motivation.

The Items of Bicycling Motivation	Component	
	Other Motivations	**Convenient**
Bicycling can improve health	0.817	
Bicycling can protect the environment	0.809	
Bicycling can save money	0.666	
It is easier to park a bicycle	0.653	
Bicycling can avoid traffic jams	0.639	
I cycle for fun	0.614	
Bicycling is faster		0.893
Bicycling is convenient		0.795
% of Variance	38.862	20.584
Cumulative %	38.862	59.445
Eigenvalues	3.109	1.647

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

4.6. Multivariate Models of the Acceptable Bicycling Distance

The multivariate models of the acceptable bicycling distance of rural residents comprise all the previously described independent variables. Multiple linear regression was estimated using NLOGIT 5.0. (Econometric Software, Plainview, NY, USA) Table 7 shows the results.

Table 7 shows that the socio-demographic attributes of rural residents do not significantly affect their acceptable bicycling distance, except for age, which negatively affects their acceptable bicycling distance. This result is inconsistent with the conclusions of the majority of the existing relevant empirical studies. Moreover, the majority of the related studies have shown that socio-demographic attributes often have more significant effects on bicycling behavior than other variables [12,64]. This finding is significantly related to the fact that there is no fixed income for the left-behind population in rural areas in Sichuan and that the left-behind population members are generally older, young, or female-dominated. The following subsections mainly analyze the impact of the individual bicycling psychology and rural built environment on the acceptable bicycling distance of rural residents.

Table 7. Multiple linear regression results of the acceptable bicycling distance.

	Original Linear Regression		The Result of Linear Regression without Insignificant Variables	
Variables	**Coef.**	***p*-Value**	**Coef.**	***p*-Value**
Constant	2.494 ***	0.000	2.615 ***	0.000
Male	0.071	0.362		
Age	−0.033	0.279		
Income	−0.007	0.751		
Cycling ancillary facilities	−0.018	0.636		
Bicycle lane conditions	0.034	0.363		
Safety	0.170 ***	0.000	0.171 ***	0.000
Other motivations	0.043	0.287		
Convenient	−0.084 **	0.026	−0.080 **	0.049
Physical activate	0.395 ***	0.000	0.398 ***	0.000
Go to work/school	0.293 ***	0.003	0.281 ***	0.009
Bike with children	−0.083	0.433		
Go shopping	−0.528 ***	0.000	−0.542 ***	0.000
Visit friends	0.192 **	0.029	0.113	0.233
To entertainment	0.005	0.963		
Others	−0.318 ***	0.003	−.340 ***	0.004
Liking riding motorcycles	0.084 ***	0.010	0.116 ***	0.010
Liking riding electric bicycles	−0.083 **	0.011	−0.073	0.186
Liking bicycling	0.167 ***	0.000	0.054	0.322
O_P (Table 3)	0.098 **	0.019	0.144 ***	0.000
O_M (Table 3)	−0.063	0.210		
O_S (Table 3)	−0.056	0.261		
O_H (Table 3)	0.139 ***	0.000	0.125 **	0.011
P_S (Table 3)	0.056	0.352		
P_M (Table 3)	0.029	0.677		
P_P (Table 3)	−0.139 ***	0.002	−0.117 ***	0.001
P_H (Table 3)	0.015	0.770		
Rho-squared (R^2=1-(L(β)/L(c)))	0.274		0.243	
Number of observations	374		374	

** Significant at the 5% level. *** Significant at the 1% level.

4.6.1. Influence of the Psychological Factors of Bicycling on the Acceptable Bicycling Distance

Table 7 shows that the individual psychological factors of bicycling of each respondent significantly affect the acceptable bicycling distance of rural residents. Safety attitude (i.e., third common factor) on bicycling infrastructure conditions has a significant and positive influence on the acceptable bicycling distance of rural residents. This result notes that small motor vehicle traffic, dedicated separate bicycle lanes, and secure bicycle parking lot at the destination can significantly encourage rural residents to accept long bicycling distances. Note that 75.67% of the respondents believe that the good quality of the route surface can encourage them to ride a bicycle. However, this infrastructure does not significantly affect the acceptable bicycling distance. That is, the bicycling infrastructure conditions that meet the requirement to choose bicycles and acceptable longer bicycling distance are not precisely the same. The special separate bicycle lane can encourage rural residents to choose bicycles but also satisfy their requirement for long bicycling distances.

For bicycling motivation, the second common factor (i.e., convenience) significantly influences the acceptable bicycling distance of rural residents. In particular, rural residents who believe that bicycling is convenient and fast are reluctant to ride long distances. Instead, they believe that short-distance travel can better reflect the convenience brought by bicycles. Thus, people who think that bicycles are convenient and fast may ride bicycles frequently. This conclusion indirectly coincides with the conclusion of Fu and Farber on bicycling frequency [12]. Although 83.43% of the rural residents believe that bicycling can enhance physical fitness, this bicycling motivation does not significantly affect their acceptable bicycling distance. Similar bicycling motivations include protecting the environment and saving money. Therefore, motivation and specific behavior are not constantly consistent [65].

For bicycling purposes, five of the seven indicators significantly affect the acceptable bicycling distance. Among the indicators of bicycling purpose, physical activity had a significant and positive influence on the acceptable bicycling distance of rural residents, with the largest impact coefficient among all the influencing factors. However, only 10.70% of all the respondents selected physical activity as their bicycling purpose. That is, only a few residents in the rural areas of Sichuan are bicycling for physical activity. However, if the respondents selected physical activity as their bicycling purpose, then they would accept long bicycling distance. Fu and Farber [12] studied urban residents and showed that 79.55% of the respondents ride bicycles for physical activity, although this endeavor did not significantly affect their bicycling frequency. Thus, the two similar research results indicate that the influence of bicycling purpose on bicycling behavior is indirectly related to the number of respondents who select this bicycling purpose option. Moreover, bicycling to work and school and visiting friends has significant and positive effects on acceptable bicycling distances compared with daily shopping and other purposes of transportation. This aspect reflects the current status of the daily destination distances of rural residents. Typically, workplaces, schools, and relatives and friends are not close to home. For the purpose of these trips, the acceptable bicycling distance is relatively distant (subconsciously). Other daily trips, such as shopping, are often selected at a nearby market or the nearest convenience store. Hence, the acceptable bicycling distance is considerably short.

For riding preferences, this study mainly considers the influence of the likeness of bicycles, motorcycles, and electric bicycles on the acceptable bicycling distance of rural residents. The research results (see Table 7) show that all indicators of the riding preference have a significant impact on the acceptable bicycling distance of rural residents. This result indicates that liking bicycling is the most important factor in explaining bicycle ownership and use [49]. Moreover, liking bicycling is closely related to acceptable bicycling distance [49,50]. The indicators of liking riding a bicycle and motorcycle positively affect the acceptable bicycling distance of rural residents, with liking riding a bicycle having a considerable impact. Thus, rural residents who like bicycling can accept long bicycling distances. Furthermore, those who like to ride motorcycles can accept relatively long bicycling distances. By contrast, rural residents who like riding electric bicycles would accept short bicycling distances. This research conclusion completely illustrates the complementarity of bicycles and motorcycles for travel and the mutual replacement of bicycles and electric bicycles [63].

4.6.2. Influence of the Rural Built Environment on Acceptable Bicycling Distance

Table 7 shows that two of the four objective built environment indicators significantly influence the acceptable bicycling distance of rural residents. The distance from the village center to the nearest health center (O_H) and public transportation station (O_P) has a significant and positive influence on the acceptable bicycling distance of rural residents. That is, the distance between the two locations has a substantial influence. Moreover, the distance from the village center to the nearest school has a significant negative impact on the acceptable bicycling distance. Note that the authors of this study perceive that the market is a trading center in the rural areas of Sichuan and should significantly influence the bicycling behavior of rural residents. However, the market is not significant in this study. The indicators of the perceived built environment of the rural residents have limited impact on their acceptable bicycling distance. Only the perceived convenience to public transportation station significantly and negatively affects the acceptable bicycling distance. This result indicates that rural residents who believe in the convenience of going to public transport stations will accept short bicycling distances. This result is consistent with our expectations.

This study compares the influences of the objective and perceived built environment on acceptable bicycling distance of rural residents and determines that only the perceived and objective health center built environment indicator significantly influences the acceptable bicycling distance of rural residents.

However, the effects are opposite. This result shows that the objective and perceived built environment have relatively independent effects on the acceptable bicycling distance of rural residents. Moreover, this result is consistent with that of [2] on bicycle frequency.

The multiple regression model was used to explore the socio-demographic attributes, individual bicycling psychological factors, and rural built environments on the acceptable bicycling distance of rural residents. The R-squared of the linear regression is 0.274 and the significance of the F-test of the model is 0.000. Therefore, the model rejects the null hypothesis (all parameters are zero). Moreover, this study re-estimated the linear regression model by dropping out the insignificant variables and the results are similar to the initial model (see Table 7). Therefore, the results are consistent with our assumptions and this study adopt the original model to interpret the relationship between dependent and independent variables for more information. The influence of the individual bicycling psychological factors of rural residents on their acceptable bicycling distance is significant, followed by the built environment indicators, whereas the impact of social demographic characteristics is limited. However, the socio-demographic characteristics in the relevant research literature significantly affect travel behavior [2,12,63]. This finding may be related to the characteristics of the left-behind population in rural Sichuan.

5. Strengths and Limitations

Given that this study is the first on the bicycling behavior of rural residents in Sichuan, the current research completely considers the impact of the individual bicycling psychological factors on the acceptable bicycling distances of rural residents. This research also compares and analyzes the influences of the objective and perceived built environment of rural residents on their acceptable bicycling distances. Thus, the current study substantially contributes in explaining the bicycling behavior (i.e., acceptable bicycling distance) in rural Sichuan (i.e., undeveloped areas). Moreover, this study deployed two multivariate models to accurately fit the relationships between variables. Accordingly, the results are consistent.

This study has two limitations. First, cross-sectional data were used without considering the impact of changes on the rural built environment and the psychological determinants of rural residents on the acceptable bicycling distance. Second, the aggregate data of the objective built environment in rural areas used in this study (i.e., distance from the village center to various destinations) do not specify the distance from each sample family to various destinations. Therefore, accurately obtaining the inner link between the objective and perceived built environment is virtually impossible. This finding is mainly the result of lack of rural geographic information data. Thus, additional research in the future is recommended.

6. Conclusions and Policy Implications

An increasing number of studies have focused on bicycling frequency and choice for residents in large cities. The number of rural household bicycles has continued to decline owing to rapid urbanization and new rural construction in China. In all modes of travel, the proportion of bicycling is the lowest. The current study uses face-to-face questionnaire survey and on-site measurement data to analyze the impact of individual bicycling psychology and built environment on the acceptable bicycling distance of rural residents. The purpose of this research is to provide a theoretical basis for the ecological construction of new rural areas in China and encourage low-carbon travel for rural residents.

The results suggest that further investment in the construction of special bicycle lanes is needed to provide efficient road infrastructure for rural residents, thereby encouraging them to choose the bicycle mode and bicycle use. Moreover, separating bike lanes from motor vehicle lanes reduces motor vehicle traffic. The perceived convenience and speed of rural residents for bicycling will encourage them to travel short distances. Therefore, daily destinations, such as grocery stores, shops, and markets, should be completely considered within the range of the acceptable bicycling distances of rural residents (e.g., the average acceptable bicycling distance is 2.873 km; see Figure 4). The riding preference of rural residents significantly affects their acceptable bicycling distance. Therefore, local governments should increase the provision of information on the advantages of bicycling, such as benefits to physical and mental health, zero carbon emissions, and environmental protection, to stimulate rural residents to like bicycling. To address the bicycling requirements of rural residents, local governments and provincial agencies planning the construction of new rural areas should consider the impact of objective rural infrastructure and perceived built environment on the travel behavior of rural residents.

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